ISSUED BI-MONTHLY SERIES 3, No. 2

BULLETIN

COLLEGE OF ENGINEERING

West Virginia University

Department of Mining Engineering

Mining Extension Instruction Pamphlet S-1

Mine Cars and Mine Tracks

SEPTEMBER, 1917
MORGANTOWN, WEST VIRGINIA
PUBLISHED BY THE UNIVERSITY

Entered as second class matter March [illegible], [illegible], at the post office at Morgantown, W. Va., under the act of August 24, [illegible].

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BY

E. N. ZERN, E. M.

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MORGANTOWN

ESTABLISHED FEBRUARY 7, 1867

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INTRODUCTORY.

Transportation of coal from the working face to the mine opening is one phase of mining which has undergone steadily progressive changes during the past decade. Mine cars, as a part of the transportation system, have shared in the modernizing processes, as is witnessed by the adoption of roller-bearing wheels, steel in place of wood, lift gates, etc. Mine tracks likewise have shared in the improvements, and there is no longer amazement on hearing of sixty to eighty-pound steel rails on main haulages, graded roadways with deep cuts and fills, rock-ballasted tracks, etc.

This pamphlet is the fifth of a series issued by the Department of Mining Extension on subjects pertaining to the extraction of coal. Its purpose is to assist in a better understanding of the many details which enter into the selection of mine cars and the adoption of mine track standards.

We are indebted to the following manufacturers for illustrations appearing in the following pages:

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MINE CARS AND TRACKS

By E. N. Zern, E. M.*

Part I—MINE CARS.

VARIETY OF TYPES.

The car is the universally adopted medium for conveying the coal from the working places to the surface. As might be expected, owing to the great variety of conditions encountered in mining, cars vary greatly in construction and in details. Height of seam, bad top, heaving bottom, quality and use of coal, methods of payment for coal loaded, dimensions of shaft, etc., all exercise an influence on car design.

Before a definite selection of equipment is made, every consideration should be given to the many aspects having a most important economic bearing on the successful working of the property. The size of the car, its dimensions, its shape, the materials entering into its construction, kind of wheel, bearing, axle, the choice between a tight end and an open end car, lubrication, etc., all have an influence on the selection of a proper car.

With mine cars, as in track work, we can find much to sustain the charge that there is as yet no standardization. The head of one important manufacturing firm states that they have in their shop-files over 2000 drawings of mine cars of different patterns, and of varying size and dimensions. The statement is further made that they never yet, in their experience, have built identically the same car for any two companies.† If other firms could be heard from the situation would appear still more astounding. This causes one to wonder whether there is great dissimilarity between all mines operating in the same seam in a given locality. Ample testimony to the contrary can be had. While it is admitted that a car of given size and shape may not be suitable to each of two mines operating in different seams and under different mining conditions, yet the fact remains that in many localities (the Fairmont-Clarksburg region of West Virginia for instance) the same general type of car prevails, though there is a wide variation in dimensions and details. Uniformity of conditions here, as frequently elsewhere, is favorable to standardization. If one corporation can adopt a standard car for all

*Lecturer on Mining, West Virginia University.
†Coal Age, Vol. 8, pg. 24.

its mines, as is sometimes done, it may be construed as an argument that neighboring mines might use a wagon identically the same in design.

In this pamphlet there will be discussed in a general way the principles which govern the selection of the many details which enter into the construction of a complete mine car.

HISTORICAL SUMMARY.

The carrying of coal in sacks, as is well known, is the earliest recorded means of conveyance. An improved mode of movement was by tubs, or corves. Boys and women were engaged in the work of conveying the coal from the face to the shaft. They crept on their feet and one hand, dragging the tub along with the other hand—an extremely arduous task. "Women were dressed as boys, in trousers, crawling on all fours, with belts round their waists and chains passing between their legs."§

Female labor continued until 1842 when, to the chagrin of many of the operators, who freely predicted the ruin of the industry, their employment underground was prohibited by an act of Parliament. With the advent of metal rails, tubs gave way to wagons fitted with four wheels, which served as the prototype of our modern mine car.

MATERIALS OF CONSTRUCTION.

Mine cars are built of wood and steel. Cars built of steel with wood replacing some of the steel parts are known as composite types.

Wood.

White oak is chiefly used, the bottom boards being usually 3″ thick, the side, flare, door, and end boards 1½″ thick. There is considerable deviation from these dimensions, bottom boards alone varying from 2″ to 4″. The attractiveness of the wooden car lies in its cheapness, lack of stiffness in riding, and the ease with which repairs can be made using unskilled labor. In many localities where lumber and labor is cheap, wooden cars are built in the mine shops, the iron parts, trucks, etc., being supplied by the manufacturer.

§Report of Royal Commission.

Steel.

The superiority of the steel car is being generally recognized, and it is gradually supplanting wood. Its advantages are: (1) with the same dimensions as a wood car it will hold 10% to 20% more coal, or, in low seams, it may be cut down 4" to 6" in height and hold the same amount; (2) in this latter event it requires less muscular effort to load; (3) the cost of maintenance is less; (4) it withstands shocks and survives wrecks that would smash a wooden car; (5) owing to its stiffness it does not droop at the ends like a wooden car; (6) it makes a tighter car and minimizes the loss of fine coal in transit.

Balanced against these desirable features are its higher cost, about 40% more than a wood car; its lack of flexibility in riding; corrosion of the steel; the difficulty in making repairs and the skilled labor required in such work.

The steel plates used for the sides may be in one piece bent to the shape of the car, or in sections fastened together with bolts or rivets. The object in the use of bolts is to facilitate the detachment of any damaged portion and the subsequent replacement after straightening. When rivets are used a damaged car is straightened by heating with blow torches and hammering, or else by the use of rail benders and jacks. At some mines a crib or cage of ties is built, just large enough to admit a car, which is straightened by means of jacks placed between the crib and the car, and acting in opposite directions. Often, even when the straightening has been carefully done, there is trouble with the closing of the end gate, since the alinement is never quite the same as before the accident. Here it may be observed that tight end cars offer an undoubted advantage, since any imperfection in alinement would not be noticed with a rotary dump.

Composite Cars.

The use of steel bottoms has, in many instances, been found objectionable owing to the rapid corrosion which sets in, and which is here more noticeable than on the sides. In place of steel, therefore, wood may be specified. Such a composite type costs less than the all-steel car, though 25% to 30% more than a wood car. Besides increasing the durability of the bottom, it is less stiff and rigid than the all-steel car, and usually less expensive to keep in repair.

SIZE OF MINE CARS.

The American mine car greatly exceeds in size that used in England and Continental Europe, where, owing to the working of thin seams, the dimensions of the car are necessarily restricted. Many of the cars in use abroad hold as little as 800 pounds of coal, the preferable size carrying 12 to 14 cwts. This compares with the large cars found in the anthracite regions of this country, and even in the bituminous fields, where cars holding as much as 8000 pounds are used.

It will be found in the discussion of mine tracks that the thickness of the seam limits the height of the car; the width of the entry, dependent upon the condition of top and bottom, limits its width, while the allowable wheel base governs the length. Given a low seam with good top a car of great breadth may be used, but here we are confronted with a difficulty in construction, i. e., making strong the sides of the car overhanging the wheels. Increasing the gage decreases the overhang, but this involves an additional money outlay in track construction. Greater length of car may be attained by increasing the wheel base beyond 28" or 32", as generally found, but the hesitation here is due to the difficulty in replacing derailed cars, and the large radii necessary to provide a smooth movement between tangents.

The remaining variable is the height of car. In general practice this is directly proportional to the height of the seam, cars used in the Pittsburgh seam running as high as 52" above the rail, while in the low seams cars half this height are used. While conditions will be such that there is little choice as to the height of car in low seams, the question may well be asked what is the desirable height in a thick seam?

Nature of Work.	Weight Moved or Resistance Overcome In Pounds.	Velocity of Movement. Ft. Per. Sec.	Work Done Per Sec. Ft.—Lbs.	Time of Working, Hours Per Day	Work Done Per Day Ft.—Lbs.
Shoveling Up Earth; Lift 5 Ft., 3 in.	6	1.3	7.8	10	280,800

In seeking an answer, increasing consideration is being given by engineers to the researches of men like Poncelett, Morin, Rankine, Taylor, and others, who have conducted careful investigations to determine the muscular energy of men.

The data here given are of interest in connection with the loading of coal:

"The work of Dr. F. W. Taylor shows that a maximum amount of shoveling may be accomplished by the use of a shovel taking up a load of 22 lbs.; also that by the introduction of rest periods at stated intervals (determined from a study of the particular task) the amount of work done in a day by a laborer may be greatly increased over the figure given."*

Accepting the figure given, 280,800, as the work in foot pounds possible to be done per day, let us apply this to the task of loading coal into two cars having heights of 52" and 32" respectively above the rails, adding 6" in both cases for clearance. The number of pounds of coal shoveled in the first instance in a day of ten hours would be 280,800÷4.833 feet= 58,100 lbs., or about 29 tons. In the case of the low car we have 280,800÷3.167 feet=88,664 lbs., or about 44 tons. The meaning of this then is that with the low car, the average man can load 44 tons of coal per day with the same muscular effort as is required to load 29 tons into the high car. The difference, of 15 tons, represents the disadvantage to both mine owner and coal loader in having a car of excessive height. The fact that the tonnage figures mentioned are not reached in the mine does not alter the percentage in favor of the low car. That the advantage in its favor is not fanciful is indicated by the specifications of several large producers, who, with the privileges accruing from mining a thick seam, yet stipulate that the height of car top above the rail shall not exceed 32 inches. As might be reasonably expected, their experience has shown that the laborer realizes the advantage of the lower car and will willingly load more coal in a lower car at the same price than he will in a higher one. In addition, there is less breakage of the coal, a point of considerable importance in most localities. With low cars, equilibrium is more stable, as the center of gravity is low.

Assuming then the selection of a low car, a large capacity can be obtained only by increasing the length and the breadth. If the inside length of the car be extended to 10 feet, which would appear to be a desirable maximum owing to the throw of the coal in loading, the wheel base will also need to be increased. In some mines this now amounts to 48 inches. With such a length not only are easy curves necessary, but, moreover, every precaution must be taken to keep the track and rolling stock in good repair, so that derailments will be few. The maximum breadth of a car, assuming favorable external conditions, would appear to be about 6'-6", the overhang with

*See Mark's Mechanical Engineer's Handbook, pg. 863.

a 48" gauge being about 16 inches. A car with the following dimensions, 10 feet inside length, 6'-6" in breadth, and 32" in height above the rail, would have a capacity of about 100 cubic feet, or 2½ tons of coal level full. By careful topping an extra ton could be added.

A division of opinion exists respecting the merits of large mine cars. Those opposed point to the excessive weight, the loss of time when derailments occur, the difficulty men have in bringing them to the face, the need of heavier rails, ties, spikes, etc., and the higher initial cost. Those, contrary-minded, bring forth proof to show that even though the large unit is heavier, the improvement in wheels, axles, and bearings make it easier running than the light cars of former years; that derailments are due to carelessness in construction and maintenance of tracks, and can be largely avoided; that in most mines cars are hauled to the working places by animal or mechanical power, and that the higher initial investment is more than offset by the increased daily tonnage. It is beyond question that in many of the details connected with the delivery of the car from the working place to the tipple, and its return, the same time and effort is required with the small car as with the large. A survey of the field indicates that the trend is toward the larger car, the probable limit being a capacity of from 3 to 4 tons of coal.

It is plainly true that the car which shows the greatest ratio of useful weight (coal carried) to tare (car weight) will be the most economical in power used, everything else being equal. Kerr* states that a "tub to hold 10 to 12 cwts. should not weigh more than 4 cwts., if constructed of wood, or 5 cwts. if of iron." The ration here on a basis of 100 pounds is about 72 to 28, and refers to small cars. The statement has many times been made that large cars show a more favorable ratio in this respect than small ones, a statement hardly borne out in practice.

The table following shows the ratio obtaining between cars of light weight, medium weight, and heavy weight. All of the figures on light cars, and the first two given under medium weight, are taken from Bulletins of the Illinois Coal Mining Investigation by S. O. Andros. The tare on the remaining cars has been given by the manufacturers; the weight of coal has been either figured from the cubical contents, or from capacities as given by the manufacturer, with an allowance of 20% for topping. This allowance is, in many cases, insufficient, since cars of 77 cubic feet capacity, rated at 2 tons, are sometimes loaded with from 3 to 3½ tons of coal, and cars

*Practical Coal Mining, pg. 226.

rated at 1¼ ton may by careful topping be loaded to 2 tons. While the ratios in the case of medium and heavy weight cars are, therefore, in all probability too low, it will nevertheless be seen, after making allowances, that no great difference exists.

The failure of the large cars to show any advantage is due to the use of steel in place of the lighter wood, the use of heavier wheels and axles, draft gear, etc., all of which add greatly to the dead weight carried.

Light Cars.

Tare.	Capacity of Cars in Lbs.	Ratio of Coal to Tare.
800	2000	72—28
900	3000	77—23
1000	4200	80—20
1100	2600	70—30
1200	2600	68—32
1300	4200	76—24
1400	3000	68—32
1500	3500	70—30
1600	3000	65—35
1700	5000	75—25
1750	5600	76—24
1900	4000	68—32
2000	5000	72—28
Average ratio		72—28

Medium Cars.

2200	6000	73—27
2400	6000	71—29
2525	4000	61—39
2665	4800	64—36
2850	4800	63—37
Average ratio		66—34

Heavy Cars.

3240	6500	67—33
3330	6000	65—35
3500	6500	65—35
3700	8000	68—32
3780	6750	64—36
Average ratio		66—34

How to Figure the Capacity of a Mine Car.

The prevailing cars in bituminous mines are either of the single flare or double flare type as shown in Figure 1.

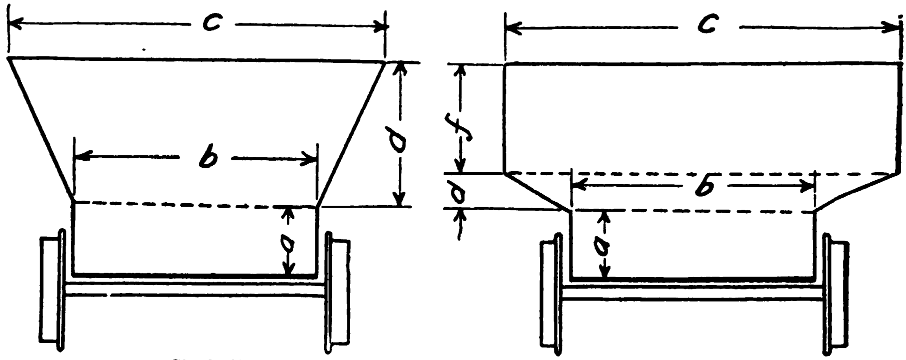

Fig. 1. Types of Mine Cars.

The first step in determining capacity is to find the cross sectional area. Assuming first the car with a single flare, the area can be divided into two parts as shown by the dotted line, the lower part having the form of a rectangle and the upper part that of a trapezoid. All dimensions are to be given in feet.

The area of the rectangle $= a \times b$

The area of the trapezoid $= \frac{b+c}{2} \times d$

Total area of cross section $= (a \times b) + \left(\frac{b+c}{2} \times d\right)$

Multiplying this expression by L, the inside length of the car, in feet, we have,

Cubical contents $= L \left[(a \times b) + \left(\frac{b+c}{2}\right) \times d \right]$

In the case of the double flare car we have a cross section made up of two rectangles with a trapezoid between.

Area of bottom rectangle $= a \times b$

Area of trapezoid $= \frac{b+c}{2} \times d$

Area of top rectangle=c x f

Total area of cross section=

$$(a \times b) + \left(\frac{b+c}{2} \times d\right) + (c \times f)$$

Multiplying this expression, as before, by L, the inside length, we have,

$$\text{Cubical contents} = L\left[(a \times b) + \left(\frac{b+c}{2} \times d\right) + (c \times f)\right]$$

To find the number of pounds in the car when struck level, multiply the cubical contents by 50, the number of pounds in a cubic foot of loose coal.

The car used in the anthracite regions of Pennsylvania is usually box shaped, the cross section being a rectangle. The contents is, therefore, very easily found.

Referring to Figure 1, the illustration of the double flare car, the breadth of car at bottom, b, is usually taken 6″ less than the gauge of track, while the depth, a, is taken as one-half the diameter of the wheel.

END GATES AND FASTENINGS.

To provide a means of egress for the coal from the car while dumping, an end gate is fixed to the forward end. This is swung by from two to four straps on a bar, which also serves to support the car sides at the weak end. Before loading the car, the end gate is latched by the loader, a few of the many devices for accomplishing this being shown in Figure 2. The requirements of a good latch are that it shall be so simple that its operation may be easily understood; that it be so constructed as to stand constant rough usage; that it shall not become unfastened through jolting or derailment of cars on haulage ways, and that it be quickly and easily unlatched on the car dump.

Many of the devices employed have failings in one or more particulars. Latches, which are close fitting at the beginning may soon fail through the distortion of the car sides; those consisting of a hook fastened to a chain may fail through the breakage of the chain; those made up of long bars may fail through the bending of the bar and its failure to engage securely both of the side lugs. Because of such difficulties the loader often resorts to the driving of wooden wedges to fasten the latch in place, causing exasperating delays on the tipple.

The lift gate has had a rapidly increasing use, and is the standard for use at shaft mines having self-dumping cages. Its superiority over the swing gate lies in its being less liable to come open in the course of travel. It is only when the bolt fastening the straps extending from the end gate to the sides of the car becomes lost that this may happen, and not through excessive jolting on the haulways.

Fig. 2. Latches Used on End Gates.

It is true of all end gates, no matter what type of fastening is used, that the open space between the end gate and the car sides permits the leakage of fine coal on the haulway. This in time is ground fine by the passage of cars and the traveling of men and animals, and constitutes an additional element of danger in mining, inasmuch as this fine dust is carried about by the air current and would be a powerful aid in the propagation of an explosion.

Cars having drop bottoms are frequently used about mines where the trips are brought out of the mine by a rope, the coal being emptied directly into a bin by releasing the bottom. Closing is effected by the winding up of a chain attached to the bottoms, or it may be so arranged that closing is done automatically as the cars are being moved from the tipple. Drop-bottom cars are fairly common in the coke regions of Pennsylvania. They are advantageous here because with the usual long bin designed to hold a day's charge for the ovens, the long trip of cars can be brought to a stop at any desired point, and the bin filled uniformly without the necessity of chain and sprocket driven levellers. They are, however, expensive to keep in good order, leak coal in transit, and any accidental loosening of the bottom causes the wrecking of the trip.

Wagons With Tight Ends.

The presence of an end gate makes it impossible to have in the front the same strength and rigidity as found in the rear of the car. Since the sides in front are reinforced at the top only by the bar on which the end gate is hung, the front binder belt must be mainly relied upon to resist the strains encountered in the rough service to which all car equipment is subjected. In time the insufficiency of this support permits the spread of the sides and causes an ill fit with the end gate. Fine coal is dribbled along the roadways. The end gate boards become broken, and in this way, or by accidental opening in transit, enough coal may be spilled to cause a wreck. In order to prevent such an occurence a constant oversight must be exercised and the end gate and fastenings kept in good repair. During the necessary repair periods such cars are taken off the haulways and the mine is handicapped by the loss of so much rolling stock.

Cars with closed ends are free from these drawbacks. The ends being rigid and connected throughout their depth to the car sides, there is presented the strongest possible construction. All danger of accidental opening of end gate is removed, no fine coal can be spilled on the haulages, the loader is always assured of correct weight on the tipple, the item of gate repairs is completely wiped out, and more cars, therefore, are available for daily service. An additional reason which should carry much weight with the industry is that a car with tight ends can be manufactured at less cost than the end-gate type.

The reason for indifference to the economy in the use of the closed-end type of car in drift mines is doubtless due to the fact that a special type of dump, the rotary, is required for unloading the mine car. Dumps of this type, operated either by motor or by gravity, are on the market, and are giving entire satisfaction. It is a safe prediction that the tightened wagon and the rotary dump will win a gradual ascendency in American mines.

DRAWBARS.

Drawbars are found on all cars not equipped with spring bumpers, or drawheads. With cars having side bumpers the style shown in Figure 3 is used. For cars having center

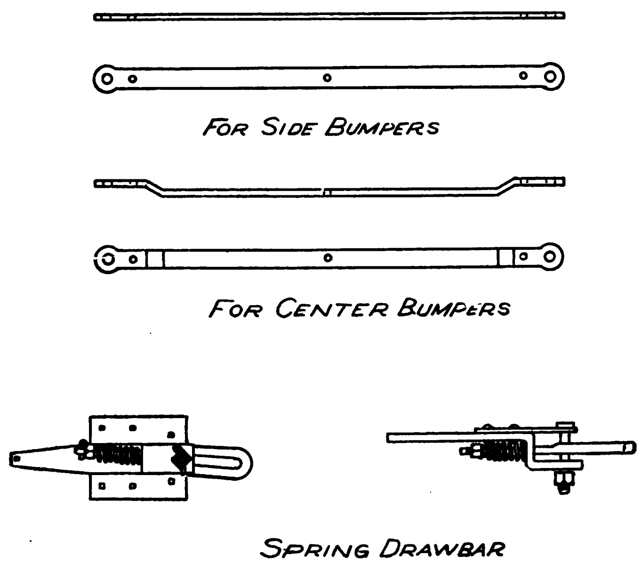

Fig. 3. Styles of Drawbars In Use.

bumpers some provision must be made to provide room for the insertion of the coupling link. This is effected by an offset at the ends, as shown in the figure.

The spring draw bar, also shown, overcomes the disadvantage of the spring drawhead, inasmuch as it adds no additional weight to the car, and is, furthermore, inexpensive. It can be used with either side or center bumper cars. Its utility lies in the absorption of shock and a greater smoothness of operation. It can be applied to old mine cars in use by merely welding the new end to the old draw bar, making no further change in the construction of the car.

Drawbars vary in width from 4″ to 5″ and are usually ⅝″, ¾″, 1″, or 1¼″ in thickness. They are connected to the car bottom by ¾″ rivets, in the case of a steel bottom, or by ¾″ bolts in the case of a wooden bottom.

BUMPERS.

Mine car bumpers are of two kinds, those consisting of two projections beyond the car, one at each side of the drawbar, and known as side bumpers, and, second, those having but one projection beyond the car, known as the center bumper. Modifications of both types are shown in Figure 4.

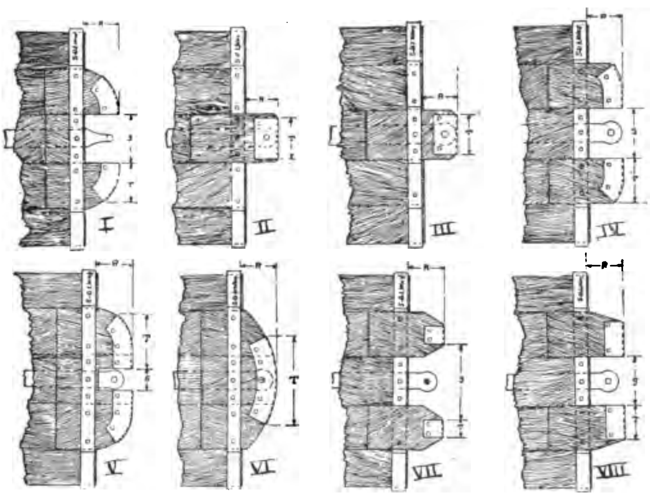

Fig. 4. Modifications of Center and Side Bumpers.

Side bumpers require long chain couplings. In passing around sharp curves there is always danger that the bumpers will inter-lock and cause derailment. Center bumpers here show a great advantage, since they allow cars to go around curves easily and safely, provided the connecting link is of the required length. In style VI, a favorite form of bumper, the radius of the face may be mathematically calculated so that the cars will roll on each other evenly when going around a curve, and only a slight play is left in the single link coupling. Center bumpers add much to the life of the equipment, as there are absent the corner bumps that strain and rack the car.

Sometimes center and side bumpers are used together, having a double bumper on one end of the car and a single bumper on the other end. This works well on inclines where there is automatic uncoupling at top.

Since with any type, the bumper must stand the shocks due to sudden stopping, or the slackening of speed, they are stoutly built of a double thickness of bottom boards.

BRAKES.

Many different kinds of brakes are used, all of them depending upon the friction produced by pressing against the wheel a body having a wearing surface shaped to the arc of contact. The brake block may be of wood or steel. In place of the block a band of steel drawn down tightly against the wheel may be made to serve.

The place of application of the brake may be above the center line joining the axles, below it, or midway between these two positions. If above, gravity tends to draw the block, when out of use, toward the wheels and may cause rubbing. This tendency, however, may be counteracted by having a sufficient release of blocks to raise them well above the wheels. If the brake is below the center line the opposite effect is had, but in case of derailment, the brake attachments are very likely to be damaged, causing additional delay and expense in restoring the car to its former good condition. This seldom happens when the brake block is above the wheels, and this is, therefore, the preferable position. The midway position is frequently assumed when brakes are to be applied on both sides of the car and operated with one lever.

When wood is used a single block generally suffices, being made in the shape shown in Figure 5. When set it exerts

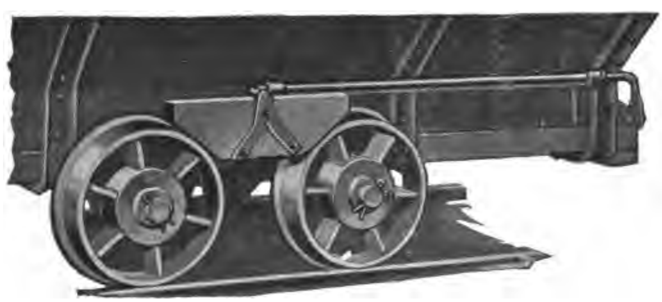

Fig. 5. The Wooden Brake Block.

a pressure against both wheels. Metal blocks are in pairs, one to each wheel. They are cast of a mixture which will resist wear though not as hard in composition as the wheel.

Sprags are used extensively in the anthracite region in place of brakes. A sprag is a pointed cylindrical stick of wood and is thrown between the spokes, locking the wheel and causing frictional resistance by the sliding of the wheel on the rail. This tends to produce flat wheels. The same bad effect is brought about by setting a brake so firmly that the wheels are locked in position and slide instead of revolving and causing frictional resistance by rubbing against the brake block.

HITCHINGS, MINE CAR COUPLINGS.

Styles of couplings commonly found in mine use are shown in Fig. 6. The single link can be used only on cars having center bumpers, and where curves of large radii are driven. The other styles are used with side bumper cars, though they may also be used with the center bumper type. Patent hitchings, parting in the middle, are on the market. They are easy of manipulation and have the further advantage that each end can be permanently attached to the car, thus being always in place and ready for use. They are so constructed as to prevent their coming apart while in service. In all of the other types one end of the coupling may be held in place by a pin with a cotter pin in the end, leaving the other end of the coupling free for connection to the adjacent car. In the double clevis hitching the pins are stoved so that they cannot pass through the upper half of the clevis and become lost.

Couplings are made of wrought iron, while clevises and pins are made in one piece of steel. In each case a high tensile strength in the material is a requirement.

Automatic Couplers; Spring Draw-Heads; Pocket Bumpers.

These are placed on cars of the heavier types, and are, in the main, patterned after the equipment used in railroad practice. The advantage of the spring draw-head lies in the reduction of shock. It also assists the motor in starting a train of loads by reason of the movement each receives due to the spring. The disadvantages are the additional weight placed on the car, and the high cost.

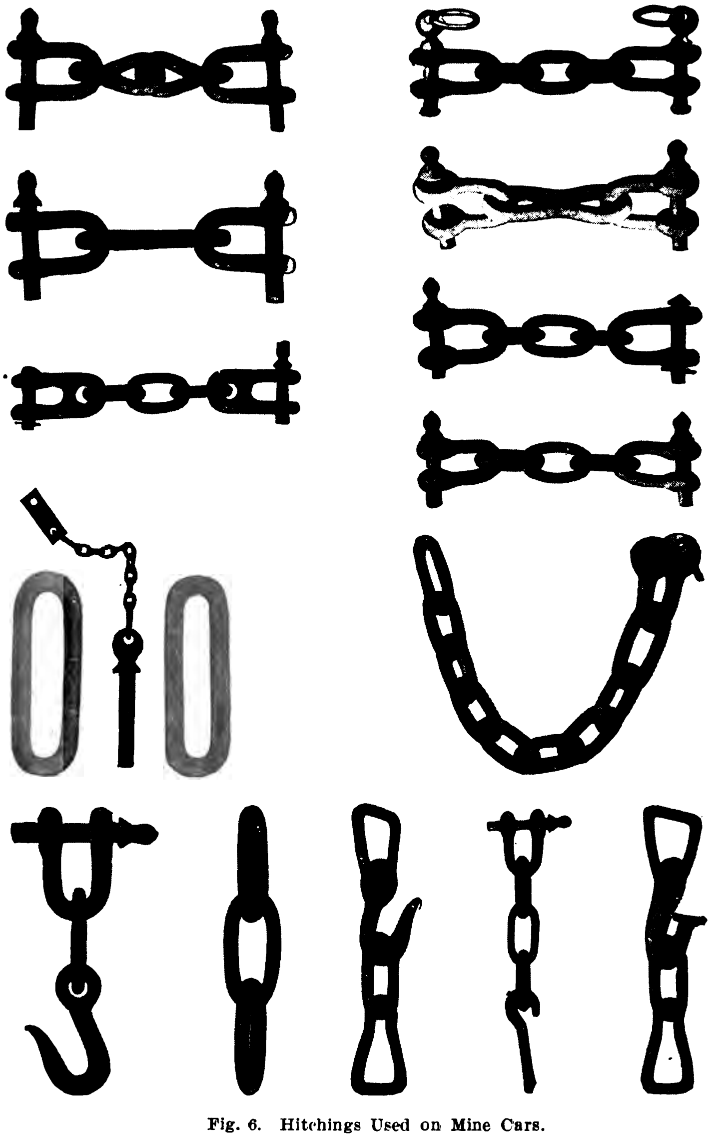

Fig. 6. Hitchings Used on Mine Cars.

WHEELS AND AXLES.

Wheels are generally 18″ in diameter, though 14″ and 16″ wheels are used with low cars.

From the standpoint of tractive effort a large wheel is much to be preferred to a small one; first, because a small wheel indents the rail more deeply than a large wheel, hence, while in motion must be lifted out of a deeper cavity; second, in passing over grit on the rail or inequalities in the road, the tractive effort, having a higher point of application, gives the larger wheel a greater moment to mount the obstacle; and, third, assuming the same load, and, therefore, the same size of axle, as, for example, an 18″ wheel in one case and a 36″ wheel in the other case, the small wheel will make two revolutions to every single revolution of the large wheel in traveling a given length of track. The hub of the smaller wheel making two rotations about the axle, the frictional loss will be twice that of the larger wheel.

The relation between the diameter of a wheel and tractive effort is expressed by the formulae:

$$F \frac{kP}{r}$$

where F=the horizontal force required at the axis of a circular body to produce and sustain uniform motion,

k =a coefficient determined experimentally
P=the load
r =the radius of the rolling body

The objections, however, to a large wheel are: first, it requires a large axle to take care of side thrust; second, it involves additional weight and cost; and, third, large wheels would affect the design of the car, tending to raise the bottom and diminish capacity. The prevailing 18″ wheel may be regarded as a compromise size.

Axles are found as small as 2″ in diameter, rising from this by ⅛″ increments up to 3¼″ in diameter. While for the purpose of reducing friction, the diameter should be as small as possible, strength is of far more importance. The size of the axle may be readily computed by considering it as a beam uniformly loaded and supported at both ends, allowing an ultimate strength of 100,000 lbs. per square inch of cross section, and using a factor of safety of 8. Since the size of the axle is clearly proportional to the tare of the car plus the weight of the coal, it follows that the larger size axles are found on heavy cars.

Originally all cars were equipped with square axles clamped tightly to the car bottom. The wear on the axle journal was not distributed over the entire circumference, being greatest at the bottom portion and in consequence after the axle had been in service for some time it wore oval and caused the wheel to wear out internally. New wheels when placed on these worn journals were soon rendered useless.

The round axle, being free to rotate and distributing the wear evenly over the entire surface of the journal, is recommended to meet this difficulty. The earliest round axle consisted of a straight piece of cold-rolled steel with a hole for a cotter pin at each end. This construction allowed excessive sideways play and collars were then shrunk on to the axles, back of the boxes, to get rid of this undesirable feature.

Hollow Axles.

The hollow axle shown in Figure 7, makes two claims for distinction; first, being hollow it is the strongest form of con-

Fig. 7. Hollow Axles.

struction, weight for weight, that can be presented, and, second, the lubricant is stored within the axle, whence it feeds by gravity out of the open end, and thence by capillary attraction and centrifugal force along the bearing surface, escaping at the inner end of the hub and lubricating the surface where wheel thrust is taken. The axle is not rigidly attached, but has floating rotary motion as well as floating endwise motion, thus equalizing the wear.

Methods of Attaching Wheels to Axles.

Four methods are possible; first, axles fixed and wheels running loose on them; second, wheels fixed to the axles, the latter running loose in journal boxes which support the weight of the car; third, wheels running loose on the axles and axles running loose in the boxing; and, fourth, one wheel fast on the axle and the other wheel loose.

On first thought it would appear advisable to follow the lead of the railroads and adopt the second mentioned, i. e., wheels fixed to the axles. This is, in fact, common practice in the anthracite regions, and has been adopted in a number of bituminous mines. A great advantage in their use is the absolute trueness of gage. The requirements are that curves be driven with large radii and that the roads be kept in good order. With fixed wheels one or both of the wheels must slide in traveling around a curve, since the outside wheel passes over more ground than the inside one.

The practice of having one wheel loose and the opposite one tight is a compromise measure. In this case both wheels revolve with the axle until a curve is reached when the loose wheel revolves on the axle just enough to relieve the slippage referred to above.

The method prevailing in most mines, other than anthracite, is to have both wheels loose on the axle. In favor of this arrangement are, first, the smaller resistance met with in passing around curves; second, cheapness as compared with the tight wheel and axle, and, third, the greater ease of renewal when worn. Where varying grades are encountered and much braking is necessary, there is always the possibility that because of setting the brakes so hard as to slide the wheels, the tread may be worn flat and make it necessary to discard the wheel. With loose wheels this involves less time and expense than with tight wheels.

Fastening Axles to Bottom of Car.

Several methods of attachment are used. The earliest method employed with the square axle, was the axle strap, one at each side of the car and bolted to the car bottom. This form is still used, as also with round axles, the strap, in this case, going around the pedestals and effecting a tying together of the running gear. A second method in use with round axles, is wide-wing four-bolt boxing, inside plates being placed on the car bottom to prevent the enlarging of the bolt holes in the wood.

It is imperative, if satisfactory results are to be derived in the running of the car, that both axles remain absolutely parallel and that they do not shift position in the direction of the length of the car. Because of a constant hard service, and more particularly owing to the manner of dumping, in which the car is thrown forward violently each time, the shock being taken always by the forward pair of wheels and the axle, there is a tendency with the axles to deviate from the parallel and with the bolt holes in the car bottom to enlarge through wear.

To guard against this requires a rigid fastening and a method for the distribution of shock. This is furnished by the use of angles, or channels, running across the bottom of the car and tied together with connecting straps, D, as in Figure 8. The

Fig. 8. The Angle-Bar Truck.

angle, E, gives a much greater support across the bed of the car than with the use of straps or plain boxing, though, on the other hand, their use introduces just so much more metal to the ravages of corrosion. Instead of two angles or channels, a one piece solid steel plate is sometimes used, but it is questionable whether this is in any way superior to the angle or channel truck.

Foundry Methods.

Car wheels are made of cast iron, which, as ordinarily cast, is a comparatively soft metal. In order to prevent rapid wear on the tread and flange of the wheel it is necessary to make these parts very hard. This is done by chilling the iron during the casting, for which purpose there is used an iron mold. The molten metal coming in contact with this is chilled and there is produced an iron in which all the carbon is in the combined form, i. e., white cast iron. This white iron represents the chill of the wheel, and it is on this that the wear of the wheel depends. Once the chill is cut through the tread of the wheel wears out rapidly. The spokes and hub of the wheel will be of gray cast iron (the carbon here being in the form of graphite) because of the slower cooling in the sand parts of the mold. These parts are therefore less brittle and better able to withstand the shocks of service.

The making of chilled castings is one of the most difficult problems of cast-iron metallurgy. Every precaution must be taken to keep the metal very close to a given composition as the chill itself will be relatively hard or soft, deep or shallow, depending upon this.

Such details as the temperature of the mold, of the chill, and of the metal when cast must be regulated with care. Only the highest grades of pig iron and carefully gathered scrap metal should be used. Because of the certainty of analysis, manufacturers try wherever possible to get back their own wheels after they have been worn out. Other manufacturers condemn the use of any scrap whatever, this prohibition extending even to the re-use of old car wheels of their own make. Sulphur is responsible for this ruling. Every car wheel contains this objectionable element, though it is held to a low point. The old wheel, in being melted in the cupola, comes in contact with coke, which imparts to it additional sulphur, producing in the finished product a higher percentage than in the initial cast of the wheel. The contention is that every wheel made from scrap contains more sulphur, and is therefore more brittle, than would be a wheel made entirely from a mixture of pig iron coming from both the coke and charcoal furnaces.

The process of chilling sets up certain strains which should be reduced before putting the wheels into service. To effect this the newly cast red-hot wheels are quickly lowered into preheated annealing pits, after which the pit is sealed and the wheels allowed to cool slowly. After removal from the annealing pit the wheel is now complete and ready for the machine shop. Here the hub is prepared for the journal, or the roller bearing, as the case may be, and for the flange on the boxing. Since these parts are of gray iron machining is easily done.

Bearings

More thought has apparently been given to wheel and axle bearings, and the possibilities for reducing frictional resistance, than in any other branch of car design. Certainly any improvement in this direction has a far reaching effect on the expense of coal production. If by the use of a superior bearing, the draw bar pull is halved, it follows that, using the same weight of motor, twice the number of cars can be hauled as heretofore, or else, that the same number of cars can be hauled with a lighter motor. Figured either way it means a saving in operation.

In the case of a plain bearing wheel we have an example of sliding friction, that is, there is continually taking place a sliding of a section of the hub past a section of the axle. By the use of rollers about the axle rolling friction may be substituted for sliding friction, and this, in brief, is the principle on which the roller bearing wheel is based.

There are two different methods of housing the rollers. They may be in the wheel hub, or else in the journal box, which is either on the inside or on the outside of the wheel. The inside journal box is more suitable for the type of car used in the bituminous fields, while the outside journal has a wide use in the anthracite regions, where owing to the heavy loads carried, journal boxes are standard. The outside journal is also found in many metal mines. The advantage claimed for the type with rollers in the box over the other is that with heavy loads the thrust against the flange of the wheel when rounding curves, cannot pinch the ends of the rollers. Rollers in the wheel are recommended on light, small cars, and in the box for heavy service cars.

The object of roller bearings is, of course, to reduce the frictional loss resulting from the rotation of the wheel about the axle. This reduction is stated to be from 40 to 60 per cent., that is, it requires 40 to 60 per cent. less tractive effort to move cars with roller bearings than with plain bearings on level track.

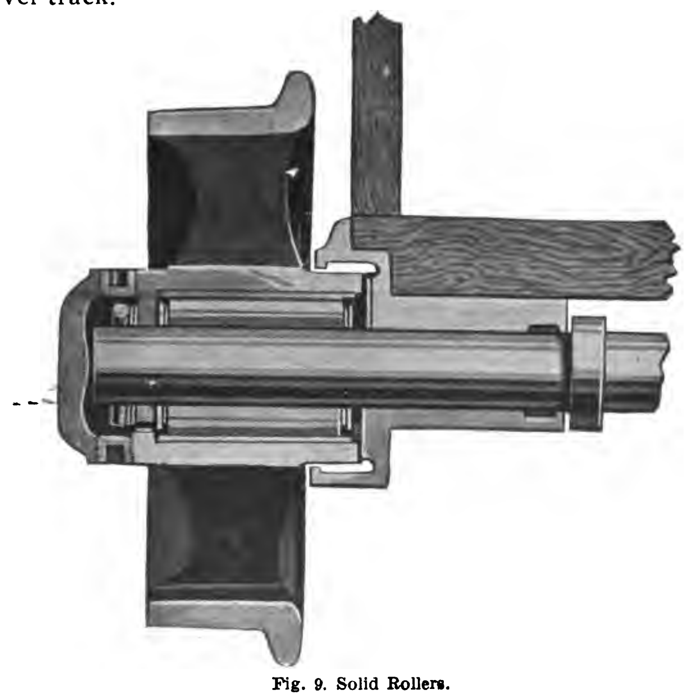

Fig. 9. Solid Rollers.

In order to maintain a lasting superiority over the plain bearing, roller bearings must stand years of hard usage. Any indentation on the axle due to pounding would necessarily affect the performance of the truck. Axles made of a higher carbon steel will resist this, but care must be taken to avoid getting the percentage of carbon so high as to induce breakage.

Two kinds of roller bearings are in use, first, the solid roller as illustrated in Figure 9, and the flexible roller as shown in Figure 10. Each type has its distinguishing features and both have demonstrated their successful application to the problem of reducing frictional losses in mine haulage.

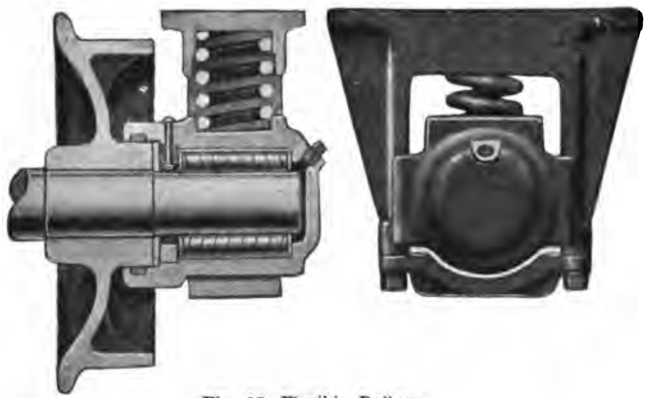

Fig. 10. Flexible Rollers.

Lubrication

Lubrication has for its object the diminishing of friction between moving surfaces. It is a requirement for easiest running that the axle shall not come in contact with the wheel but shall revolve on a thin film of lubricant. Southwick conceives the rotation of a shaft as taking place on molecules of oil, comparing it with the balls of a ball bearing.

A definition of a good lubricant would be—one that possesses minimum cohesion among its particles and at the same time maximum adhesion to the surface to be lubricated. The cardinal principle underlying all lubrication is to use the thinnest, or least viscous, oil that will stay in place and do the work.

The solid hub self-oiling, or cavity type, wheel makes use of either a cheap grade of black oil, or a semi-fluid grease. The black oils are commonly crude oils from which the more volatile portions, as the naphthas and burning oils, have been removed by distillation. The axle is lubricated by the oil coming through the passages in the wheel leading from the reservoir. This is principally the case while the wheel is at a standstill, or traveling at low speeds, as when in rapid motion, centrifugal force holds the oil in the reservoir and prevents its having access to the axle. The oil should be of such a consistency that it will feed freely through the passages and yet be sufficiently viscous to retard leakage through the wheel when it is in motion, thus leaving the axle dry and causing increased friction in proportion to the load carried. The interval between oilings depends largely upon the quality of oil used, the construction of the wheel, and the loss of lubricant through a poor fit of the axle or boxing with the open parts of the hub.

In many of the early designs of wheel little attention was given to the wastage of oil. The figures kept by one company showed that the cost of pit car oil alone was three times that of all other lubricants used at the plant.* A great deal of this waste may be prevented by employing men as oilers instead of irresponsible boys; by providing an ample and well lighted place for oiling; by using a system of markings showing the date on which each car was oiled; by using a good oiling device, such as a pressure gun, to regulate the amount of oil delivered to the wheel; and by using a wheel designed to prevent leakages.

An objection urged against thin limpid oils is that the centrifugal force developed in the revolving wheel throws the oil away from the axle, thereby preventing its lubrication. Semi-fluid oils, or greases, having more body, are presented as an alternative and are being extensively used in place of the black oils. These are made in the same manner as cup grease, the only difference being that the former is more soft bodied, there being a smaller quantity of saponified fatty oil combined with the hydro-carbon oil. The consistency does not alter under extreme conditions of heat and cold, and while it finds its way easily into the bearings it does not pass quickly out of the wheel.

Solidified greases are not used with the cavity type of wheel but are in common use with the roller bearing type. The grease shows a high coefficient of friction at first causing a rise of temperature which melts it, producing the effect of an oil-lubricated bearing. It is forced into the bearings with a pressure gun, and being thick is not thrown out by rotation, or squeezed out by the side play of the mine car. Each wheel holds about ¾ lb. of grease and at intervals of from 4 to 18 months, as needed, additional quantities are added to replace that used. Semi-fluid oils are also extensively used with roller bearing wheels.

*Mines and Minerals, Vol. 32, pg. 26.

On the matter of lubrication there are champions of each of the three forms of bearings, i. e., the square axle, with cavity-type open-end wheel; the round axle with cavity-type capped wheel; and the round axle with roller bearing wheel.

Th advocates of the first mentioned aver that the wear on the bottom of the journal is negligible if the use of "black strap" is discontinued and in its place there is employed a high grade oil or grease having such a viscosity as will make it impossible for the lubricant to be thrown out of the wheel. Instances are freely cited where such wheels run six months and longer with one oiling, though it is admitted that a poorly designed wheel will seriously affect the performance. In the next place there is no boxing to lubricate, as with the round axle, and lastly the wheel is light in weight and cheap as compared with the roller bearing wheel.

In the case of the round axle, it is admitted that there is some difficulty in getting the lubricant to the boxing, but since the axle is not expected to rotate, except sufficiently to bring about an even wear on the journal, a lack of lubrication here is not a serious detriment to the easy running of the car. At any rate such a disadvantage is small compared with the benefit of distributing wear on the axle.

The necessity of the roller bearing wheel is based on the change in haulage conditions. While cars were being moved slowly by rope or animal haulage, a very satisfactory lubrication was possible with the plain bearing type of wheel, but with the advent of electric motors and high speed haulage, the oil is prevented by centrifugal force from reaching the axle. Since with roller bearing wheels, the rollers are always in contact with the lubricant, the speed of the wheel is of no consequence.

Part II.—MINE TRACKS.

Requisites for Economical Transportation

Economical transportation of coal from the place where it is mined to the surface where it is loaded for shipment is a requirement for the successful operation of a coal mine.

To insure the highest economy there are needed: (1) favorable grades, (2) good trackage, (3) side tracks, partings, etc., to provide for the passing of trips and the assembling of loaded and empty wagons, (4) a sufficient supply of mine cars properly designed to meet the mining requirements and well maintained, (5) ample mechanical equipment selected for its suitability to operating conditions, and (6) a carefully planned and supervised system of operation.

All but the first mentioned of these are attainable by good management plus an understanding of the conditions likely to be encountered, and even here much may be done to better the prevailing conditions.

The road bed is the starting point in the endeavor for good haulage. Granted a properly drained bottom; a rail of sufficient size, well connected and laid on ties ample in size and correctly spaced; good alinement; an appreciation of the value of ballasting; and the necessary attention to maintenance—the foundation is then well laid for an economical system of transportation.

Historical Summary

Throughout the early days of the industry in England and Scotland coal was carried from the working place in sacks or baskets suspended on the back. Wheel-barrows and carts were used in many instances and are still found in ore mines where the haul is short.† These were run on the floor causing considerable jolting where the bottom was uneven. Planks laid longitudinally with the heading were then tried and the barrow run on these. The chief difficulty lay in the tendency of the planks to curl up at their ends. "A great improvement in the working of collieries was introduced or extended about this time, (1676), namely, the tram-plate. Planks had been in use for a long time, for they are described by Sir Frances North (Lord Guildford) in 1676, and on these, bulky carts on rollers, containing 4 to 5 chaldrons, or about

†For a more detailed historical account see "The Evolution of Mine Haulage," Mines and Minerals. Vol. 30, pg. 683.

12 tons, were drawn along to the staiths (landings) by one horse. These wagon-ways were greatly improved in 1765 by the introduction of cross-sleepers to tie the planks, and about the same time (1767) the Coalbrookdale Company, having an abundant stock of iron on hand during a period of trade depression. laid down cast-iron slabs on a tramway as a temporary experiment, but found so great an improvement in the transport, that the slabs were never taken up, and this is the prototype of the railways of our time. The iron tram was soon in general use at collieries above and below ground, and remained so until the introduction of the rail."‡

Rails

The cast-iron tram-plates, introduced in the eighteenth century, were succeeded by wrought-iron rails, and these, in turn, gave way to rails made of steel. The weights of steel rails manufactured for mine service are 10, 12, 16, 20, 25, 30, 35, 40, 45, 50, 55 and 60 pounds per yard. Most of the lighter weights and all of the heavier conform in section to A. S. C. E. standards. Heavier rails than the last named are used in a few mines.

In the selection of rails it is false economy to skimp on the original cost too much. A road constructed of too light a section of rail, while showing a saving in first cost, will require the expenditure of the saving over and over again in repairs and maintenance, to say nothing of the loss in delays to traffic. Each year as it passes removes the workings farther away from the mine opening and requires a longer haul. To maintain the output it is necessary that there be more cars to each trip and more speed in transit. This, in turn, obliges the use of heavier motor equipment and to bear this increased traffic, a heavy rail and good roadbed are necessities and should be provided at the beginning of the enterprise.

Since the weight of rail depends largely on the type of haulage equipment, it follows that the smaller sizes are found in thin seams where haulage is done by animal power, while the larger sections abound in the thick seams using large wagons and heavy motor equipment. As illustrating the former may be mentioned several mines in Illinois using 10 and 12 pound rails on secondary haulages. The Vesta mines at California, Pa., mining the Pittsburg seam, as an example of the other extreme, uses 80 pounds rail on their main haulages.

‡From "Coal Pits and Pitmen" by Boyd.

For average conditions the following minimum sizes of rail are recommended for general mine service:§

Weight of Locomotive.	Weight of Rail
4 ton to 6 ton	16 lbs. per yard.
6 ton to 8 ton	20 lbs. per yard.
8 ton to 10 ton	25 lbs. per yard.
10 ton to 13 ton	30 lbs. per yard.
13 ton to 15 ton	40 lbs. per yard.
15 ton to 20 ton	50 lbs. per yard.

In general it may be said that in the thicker seams using mechanical haulage, a popular selection is 40 to 60 pound rail for main haulages; 20 to 40 pound for the cross entries, and 16 to 25 pound for the rooms. For the purpose of insuring the easy movement of cars to and from the cages, tracks at the shaft bottom are frequently provided with a heavier section than used on the main haulages.

Standard angle-bars are used for connecting the heavier rails, while for the lighter rail sections and in the rooms, fish-plates are common. The practice of depending upon spikes at the rail ends to hold them in contact is to be condemned as in time these work loose, causing derailments and the consequent loss of time.

Steel Rails

Steel rails may be said to be of two kinds, first, those rolled from the original billet or new seconds and sold as billet rails; second, those rolled from used rails and sold as re-rolled rails. A description of the process of manufacture of the former does not belong here. Re-rolled rails have an extended use in mines. They are made from old rails discarded by the railroads because of wear, or sometimes because a heavier section is needed for increased traffic. These rails are purchased by mills specializing in the manufacture of the lighter sections. The process in these mills is similar to that where rails are rolled from the billet, the difference being in the starting point, a used rail in one case and a billet in the case of a new rail.

After a rigid inspection has been made for flaws, the rails are broken into such lengths as will roll into the specified lengths of light rail sections. They are then charged into a furnace where they become heated to a rolling temperature. The heated rail is then brought to the rolling mill and receives the necessary number of passes, usually seven to nine,

§From the Baldwin-Westinghouse Catalog.

making it longer in length and smaller in section as each operation until the desired section is reached. After the rail has gone through the finishing pass, it is hot sawed to the specified length, cooled, straightened, and punched for the splice bars.

In the process of heating, or annealing, and rolling, the strength of the old rail, which may have become impaired owing to crystallization, is restored.

Wood Rails.

A few years ago wooden rails for the rooms were in general use and they are still found in the smaller operations where timber is cheap. Oak is the common wood. In section they are 3" x 5", the larger dimension being placed uppermost. In length they vary from 10 to 18 feet. The continuous lengths of rails make butt joint connections and are held in place by spiking to a cross tie. The objection to wood rails is that they do not provide a strong or secure track. The rails are frequently warped and twisted before laying and in time the insecure method of fastening and the lack of attention invite the rerailment of cars. In addition they do not provide a return circuit where gathering is done by electric locomotives.

Gage

The gage of a track is understood to mean the distance between the inside edges of the heads of the rails, as shown in Fig. 1.

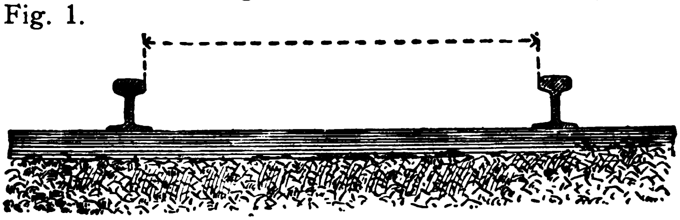

Fig. 1. Gage of Track.

In no branch of the coal industry is the lack of standardization more noticeable than in the department of haulage, and nothing can illustrate this more clearly than a view of the various gages used in coal mines. Some of these are as follows: 22, 24, 26, 26½, 28, 29, 29½, 30, 32, 33, 36, 37, 38, 39, 40, 42, 44, 48, and 56½ inches, the last mentioned being standard railroad gage, used in several West Virginia mines. The average gage in low seams is about 36 inches, while that of the higher seams is about 44 inches.

It would be difficult to explain, and much more so to justify, this wide variation in track gages. Frequently in the same seam, and under the same working conditions, a dozen different gages are found. Thus, in the Pittsburg seam, remarkable for its uniformity, gages vary from 30 inches to 48 inches. In the various Illinois mining districts this tendency is even more noticeable. It appears that insufficient thought has been given the matter and little serious effort made to determine which gage is the best suited to the purpose of economical production.

It is well, therefore, to consider briefly what factors determine track gage. The foremost of these is the local condition. The thickness of the seam determines the height of entry. The conditions of roof and bottom determine entry width The factors which limit the height and width of entry, in turn, exercise a like influence on the corresponding dimensions of the mine car. If both of these are restricting, we may, theoretically, attain capacity for the car by increasing its length, but here again we are confronted, in practice, by the necessity of a short wheel base, so that the length of the car measured inside, seldom exceeds 10 to 11 feet. Of the three restraining influences mentioned, that of width of entry is the one most susceptible of regulation. Mine cars vary in breadth and gages vary in width correspondingly.

It will be obvious from an understanding of mining conditions that no standard gage can be adopted for all mines, operating as they are in various seams and under varying conditions, but it is equally true that no justification can be found for the great variety of gages found in our coal mines. Since the result of this multiplicity is that the manufacturers of track and haulage equipment are obliged to keep in stock patterns and repair parts in large numbers, with the coal industry bearing the extra charges involved, it is in the interest of economy that gages be limited to a smaller range, such as 24, 30, 36, 42 and 48 inches. These will be found ample to cover every contingency which may be expected to arise. In addition to a direct saving effected on the purchase of equipment and supplies, the sale of second-hand equipment would be greatly facilitated.

Broad gages give a greater stability to the cars and promote smoother operation of equipment with less of wear and tear on track and rolling stock. Narrow gages permit an easier movement on sharp curves, but are prone to make the cars top-heavy. Since broad gages require longer ties they are more expensive to construct. Especially is this true where grading of the road bed is necessary.

Alinement.

The alinement of roads in modern mines is evidence of the presence of the engineer. Frequently, in the past, entry driving was allotted to the favored few who might be expected to keep a straight course, whether by sighting along the rail, by the cleat of the coal, or by a developed sense of direction. Not a few succeeded in doing creditable work, but in the majority of cases a meandering heading resulted. A satisfactory haulage under such conditions proves impossible. All of the larger companies now project their workings throughout the entire property. The direction of entry driving is governed by sights, or points, placed reasonably close to the face, and it is expected that these be used frequently to check the course of entry. With such precautions entries are driven straight and a good track alinement naturally follows.

Ballasting.

The material used for ballasting is generally the top rock overlying the coal. If the bottom be kept dry and the rock withstands decomposition due to the action of air or moisture a firm road bed is provided. Sometimes ashes from the boilers are brought into the mines and used for this purpose. Leveling of the track is done by means of a straight edge and spirit level.

Mine Ties.

Wood ties are used on main roads, cross entries and in rooms. Chestnut, oak and hard pine are the woods most frequently met with, though this depends largely upon the locality. Sassafras, elm and hickory are found in many Illinois mines. In the denuding of forests, locust is sometimes cut along with the other woods, and at least one mine in West Virginia can boast of a goodly number of walnut ties on its main haulage roads.

The dimensions of the tie used will vary according to the importance of the trackage and the weight of rail, but in general it may be said that on main haulages, using from 40 lb. to 80 lb. rail, ties should have a 6 inch to 8 inch face, be 6 inches deep, and project from 8 to 15 inches on each side of the rail. The larger projections serve to stabilize the track and to save the tie from splitting when spikes are driven. Spacing of ties varies from 18 inches to 24 inches center to center.

On side entries, using, say 30 lb. rail, a 5″ x 5″ tie with 8 to 12 inches of side projection is often used, the spacing being 24 inches center to center. In rooms using a 20 lb. rail, a 4″ x 4″ tie with a projection of 8 inches answers, the spacing being 24 inches center to center.

Mine ties, as usually supplied, are hewn on two faces with the bark on the side. It is preferable that the bark be removed since it serves to hold moisture against the tie. A sawed tie is not as good as a hewn tie. The cut of the saw leaves a more or less woolly surface which permits the retaining of moisture and encourages fungus growth.

Steel ties are coming into extended use for room haulage and have much to commend them, especially in low coal, where height above top of rail is an important item. The tie consists of a flat or corrugated length of steel provided with suitable means for securing the rail. They are usually spaced 4 to 10 feet apart, the rail resting directly on the room floor between ties. Their first cost is higher than the wood tie, but since they may be used over and over again, whereas the wood tie is seldom used more than twice, their ultimate cost is less. This comparison of costs is well presented in the tabulation shown below;*

Additional advantages in the use of steel ties are: (1) from 2 to 4 inches increase in working height is secured by their use; (2) in case of derailment the lift in replacing the car is reduced; (3) the reduction in height saves manual labor in loading the car; (4) miners are enabled to lay their own track without delay; (5) they are lighter in weight and easier to handle than wood ties; (6) the track is held at the required gage and is prevented from spreading; (7) if bent or broken they are easily repaired.

The life of the steel tie when used in rooms that are dry is stated to be ten years. In wet mines where the waters are heavily charged with acids the life may be very short. A coating of coal tar or asphaltum, applied by dipping the tie, serves as a protection against corrosion. As a further means of guarding against rust, a small percentage of copper may be added to the steel, tending to make it non-corrosive.

COMPARISON OF INSTALLATION AND MAINTENANCE COSTS BETWEEN WOOD TIES AND STEEL TIES FOR ROOM WORK IN MINES.

Based on room 280′ long with steel ties spaced at 4′ 0″ center to center and wood ties 2′ 0″ center to center.

This estimate contemplates using each wood ties in two consecutive rooms and after the 2nd year renewing annually 15 percent of steel ties, or 10 new ties per year per room.

NUMBER OF TIES IN ONE ROOM	(STEEL) 70		(WOOD) 140	
Cost of Ties f. o. b. mine in carload lots	(at .29)	$20.30	(at .06)	$8.40
560 Spikes			(at .00½)	2.80
Laying in 1st roof	(at .02) $1.40		(at .04)	5.60
Taking up when room worked out	(at .01) .70		(at .02)	2.80
Maintenance cost for 1st room Steel Ties	$2.10	2.10		
Total cost at end of life of 1st room		$22.40		$19.60
Laying in 2nd room	(at .02) $1.40		(at .04)	5.60
560 Spikes			(at .00½)	2.80
Taking up when room worked out	(at .01) .70			
Maintenance cost for 2nd room Steel Ties	$2.10	2.10		
Total cost at end of life of 2nd room		$24.50		$28.00
Saving per room in favor of Steel Ties $3.50				
10 new Steel Ties	(at .29) $2.90			
10 old ties, scrap credit	(at .05) .50			
	$2.40			
140 New Wood Ties			(at .06)	$ 8.40
560 Spikes			(at .00½)	2.80
Laying in 3rd room	(at .02) $1.40		(at .04)	5.60
Taking up when room worked out	(at .01) .70		(at .02)	2.80
Maintenance cost for 3rd room Steel Ties	$4.50	* $ 4.50		
Total cost at end of life of 3rd room		$29.00		$47.60
Saving per room in favor of Steel Ties $18.60				
10 new Steel Ties, less scrap credit	$2.04			
560 Spikes			(at .00½)	2.80
Laying in 4th room	(at .02) $1.40		(at .04)	5.60
Taking up when room worked out	(at .01) .70			
Maintenance cost for 4th room Steel Ties	$4.50	$ 4.50		
Total cost at end of life of 4th room		$33.50		$56.00
Saving per room in favor of Steel Ties $22.50				

*From Catalog of Carnegie Steel Co.

GRADES.

One of the chief considerations in opening a coal mine is the selection of a point of low elevation, so that gravity will be in favor of the movement of loaded cars. The ideal line in standard railroad location is a straight and level line, since loaded cars are moving in each direction. In mines where loaded and empty cars move in one direction only, the best grade is that in which the resistance in moving the loaded cars outward is equal to that in returning the empties. A steeper grade than this is wasteful of power both ways.

Sometimes the pitch of the seam and the location of mine opening are such that much of the haulage must be up-hill.

Again, grades may be favorable in some parts of the mine and unfavorable in others, making a succession of hills, part of the line up grade, part down grade. In some cases nothing can be done to change the natural conditions. Such conditions dictate the kind of haulage to be used.

It is true, however, that in many instances where grades are adverse, much may be done toward overcoming the disadvantage. Often by changing the course of an entry a few degrees a favorable grade may result. Where the bottom is irregular a profile may be made, after running a line of levels along the haulage, and by cutting down the high points and filling in the depressions a uniform grade of lesser degree can be established. The wisdom of flattening grades is apparent when it is realized that a short and steep grade may be the "ruling grade" and restrict the size of all trips passing on the haulage throughout the life of the mine. Under such conditions it has been found profitable to make cuts varying from 10 to 15 feet at the highest points, and to spend thousands of dollars in order that grades might be held under 1 per cent. on the main haulage.

Grades are expressed as the ratio of the rise (measured vertically) in a certain length of track to the length of the track (measured horizontally). Thus, a section of track with a uniform rise of 3 feet for each horizontal length of 100 feet would have a 3 per cent. grade. The proper method of determining a grade is by means of the surveyor's level and rod. In many cases it is sufficiently accurate to use a straight edge 100 inches in length. By placing one end on the rail and leveling it with an ordinary spirit level the vertical distance in inches from the other end of the straight edge to the top of rail will at once give the per cent. of grade.

The resistance due to a grade is always 20 pounds per ton of weight moving along it for each per cent. of grade, this being additional to the track resistance. For instance the total resistance on a 3 per cent. grade would be $(3 \times 20)+30=90$ pounds per ton, when 30 pounds per ton equals the track resistance.

CURVES.

Curves are used to facilitate movement between tangents, from main entries into cross entries, passing to side tracks, into rooms, etc.

Because of the heavier equipment now used and the speed at which it is operated, curves of large radii are required for smooth transportation. The larger the radius of the curve is the less is the resistance offered to traffic. This resistance, expressed in terms of grade, with curves of from 30 feet to 100 feet radius, will run 0.015 ft. to 0.025 ft. per 100 feet of track for each degree of curvature.* The exact value depends upon the length of wheel base, condition of rolling stock and track, and the rate of speed.

Curves of small radii are dangerous inasmuch as they permit the locking of bumpers with the consequent derailment or wrecking of trips. Provided that the curve is of sufficient radius to prevent this and at the same time afford easy movement, nothing is gained by exceedingly flat curves, since not only does this require extra length of track and power, but moreover involves costs of entry driving, maintenance, timbering, etc.

In the movement of traffic over curves the flanges of the outer wheels press against the outside rail, tending to upset it by revolving about its base. This is resisted by the spikes as is revealed by the cutting of the base into outside spikes, the pulling up of the inside spikes, and the cutting of the tie. In standard railroad practice tie plates are used, while the rails may be doubly spiked or have braces on the outside to resist this lateral pressure. With the relatively low speeds in mines and lighter loads this difficulty in curves is present to a much slighter degree, and no special provision is made for overcoming it.

Provision should be made, however, for widening the track gage on curves, since the axles are held rigidly to the bottom of the car and are thereby prevented from assuming a radial position. On sharp curves the running gear binds as the front wheel presses against the outside rail and the rear wheel against the inside rail. To overcome this an allowance should be made by increasing the distance between rails over the normal gage. The amount of this allowance will depend upon the degree of curvature, the wheel base, and the gage of track, the maximum being limited by the tread of the wheels.

Where curves must be used on heavy grades a reduction should be made in the grade used, so that the combined trip resistance, due to grade and curve, will not exceed the maximum allowed grade on the tangent. This reduction in standard railroad practice is taken as from 0.03 to 0.05 per cent. per degree. Thus with a 100 foot radius, giving approximately a 58 degree curve, having fairly clean tracks, good running equipment, etc., there would be allowable a 2.75 per cent. grade, as equaling the resistance due to a 5 per cent. grade on a tangent.

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*Coal Age, Vol. 9, pg. 969.

Owing to the low speeds in underground haulage, it is not customary to elevate the outer rail of the curve above the inner one.

The degree of a curve is defined as the number of degrees of central angle subtended by a chord of 100 feet. The radius of a 1 degree curve is 5730 feet. The degree of a curve may be found by dividing 5730 by the radius, or, the degree of the curve divided into 5730 gives the radius in feet. This method is an approximation giving fairly close results with the curves of larger radii.

Frequently curves are laid off in mines by approximate methods such as the set-in-the-dark method; by board template, 10 feet long, with a middle ordinate; string and offset method; graphic method, etc. The most dependable method is with the transit, using offsets or deflection angles. The inserted table, based on gages of 40, 44 and 56½ inches will be found useful in providing data on curves. Where gages other than the ones in the table are in use a similar table may be constructed by using the formulae with which all engineers are familiar.

TURNOUTS.

A turnout is a curved track by which a car may leave the main track for another. The essential parts of a turnout are the switch, the frog and the guard rail. The **switch** is the device which causes the car to turn away from the track on which it has been moving. To complete its passage it is necessary that one rail of the turnout track shall cross one rail of the main track; furthermore, it is necessary that the flange of the wheel pass this crossing. The device that accomplishes this is called a **frog.** As the wheel passes through the frog there is always danger that it may be turned to the wrong side of the frog point. The device which prevents this is set opposite to the frog and is known as the **guard-rail.**

There are two kinds of switches in use, the tongue switch and split switch. The tongue switch is a short, stiff switch which in opening or closing revolves at the heel as on a pivot. When closed it makes an abrupt angle with the main track, whereas it should be tangent to the turnout curve. Tongue switches are used mainly on secondary haulages and for turning into rooms. The split switch has supplanted the tongue switch on the more important haulages. Here the switch rails are planed down at one end to a wedge point, in order that it may lay close against the track rail and thus turn the